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REPORT ON THE GIPSY MOTH WORK IN NEW ENGLAND.[1]

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In Charge of Gipsy Moth and Brown-Tail Moth Work.

INTRODUCTION.

On March 1, 1913, the gipsy-moth work conducted by the Bureau of Entomology, U. S. Department of Agriculture, was reorganized, and the writer was placed in charge under the direction of the chief of the bureau.

The object of this Federal work is to use every measure possible to prevent the spread of the gipsy moth and the brown-tail moth[2] to uninfested parts of the United States.

The main office, which is maintained at 43 Tremont Street, Boston, Mass., furnishes quarters for the men in charge of the main projects and the necessary clerical force. The Gipsy Moth Laboratory, which serves as headquarters for the experimental work, is located at Melrose Highlands, Mass., although one branch of this work is conducted at the Bussey Institution at Forest Hills, Mass. During the past two years a summer laboratory has been maintained for special experiments at Worcester, Mass. A storehouse is located at Melrose Highlands, Mass., where the necessary tools and equipment are stored and repaired.

The work is divided into two distinct lines: (1) Field work, consisting of scouting, and applying hand methods for controlling these insects, as well as a thorough inspection of the plant products shipped from the infested area, and (2) experimental work, which includes the introduction of parasites and natural enemies, together with careful studies of the food plants and other factors, in order to devise more efficient and effective methods of control, as well as an investigation of the relation of silviculture to the gipsy-moth problem. A

[1] This publication is prepared to show the different lines of work which are being taken up and the results that have been secured.

[2] The life history, habits, and methods for controlling these insects have been published in Farmers' Bulletin 564, U. S. Department of Agriculture.

general outline of the problems and investigations and the different activities of the work has already been published[1] in the Journal of Economic Entomology.

During the fiscal year which ended June 30, 1914, an average of 275 men was employed. The greater number were engaged in field operations, but a force of approximately 40 men were employed on different phases of experimental projects.

EXPERIMENTAL WORK.

In carrying on measures for the control of any insect pest it is necessary to conduct many experiments in order to determine the means which are most feasible for reducing the damage. For more than 20 years experiments have been carried on more or less continuously by the State of Massachusetts and other States to which the gipsy moth has spread, as well as by the Bureau of Entomology, for the purpose of perfecting field measures for holding the insect in check, and from time to time improvements have been made which have reduced the cost of handling infested areas. Spraying machinery has been developed so that at the present time it is entirely practical to treat large areas at a moderate cost. The banding of trees with tanglefoot has largely replaced the use of burlap bands and reduced the cost of this method of treatment. In fact, so much work has been done along these lines that the best methods of treatment are well understood and practiced in the areas where the gipsy moth is prevalent. Minor improvements are being made from time to time but in general satisfactory methods of hand suppression have been adopted.

In 1905, when the Federal gipsy-moth work was being organized, it was considered very necessary and desirable to introduce the parasites and natural enemies which occur in foreign countries of both the gipsy moth (*Porthetria dispar* L.) (Pl. I) and the brown-tail moth (*Euproctis chrysorrhoea* L.) (Pl. II). The idea was prevalent that by securing and liberating these natural checks on the increase of these species, it would be possible greatly to reduce the damage, and it was hoped that the parasites would bring the pests as well under control as is the case in Europe. Accordingly arrangements were made by Dr. L. O. Howard, Chief of the Bureau of Entomology, for the collection of a large amount of parasitic material in various European countries, and later similar arrangements were made with entomologists in Japan. This work was carried on for the first five years in cooperation with the State of Massachusetts. Several agents of the Bureau of Entomology have been sent to Europe on different occasions to investigate conditions and forward to this country as large an amount of parasitized material as could be collected. For two seasons this work was conducted by Mr. W. F. Fiske, who was assisted in the summer of 1912 by Mr. L. H. Worthley. Various

[1] Jour. Econ. Ent., v. 7, No. 1, p. 83–87, Feb., 1914.

assistants and collectors were engaged to obtain parasitized material which was forwarded to the Gipsy Moth Laboratory at Melrose Highlands, Mass. After the completion of the foreign work in 1912, it appeared that not only were the parasites, and a contagious disease known as the "wilt," prime factors in controlling the gipsy moth in Europe, but in addition to these a pronounced obstacle to the increase of the pest arose from the fact that forest conditions, particularly in Germany, furnished in the main unfavorable food for the caterpillars. The observations indicated that this factor, in addition to the natural enemies already mentioned, was responsible for rendering the gipsy moth of slight importance to forest growth except at periodic intervals.

In 1912 a number of areas were under observation by Mr. Worthley in the forests of Germany, and at that time the infestation was severe. Deciduous trees in these areas were defoliated and in some cases many trees completely denuded of foliage. Similar studies were made by Mr. Fiske in Italy, where a few infestations were found which were more serious, if possible, than those observed in the German forests. During the summer of 1913 no agent of the bureau was engaged in making foreign observations on the gipsy moth. It seemed best in the spring of 1914 to have the areas in Germany revisited for the purpose of determining the result of the previous infestations and to secure data on the increase or the decrease of the species. Accordingly, early in the spring of that year, Dr. John N. Summers, who for a number of years had been in general charge of the parasite work at the Melrose Highlands Laboratory, was detailed to visit the areas mentioned and to secure all the data possible on the fluctuations of the gipsy moth, as well as to obtain parasitic material for shipment to this country, in case it could be found in collectible quantities. The result of this work has been reported by Dr. Summers, and it appears that in no place in Germany where the insect was reported in 1912 was there a severe or even moderate infestation in 1914. It was impossible, therefore, to obtain parasitized material, and in most cases the insect was so rare that little data beyond the mere fact that it still existed in the areas could be secured.

About the middle of June a report was received that a heavy infestation of the gipsy moth occurred in the Province of Bereg, Hungary. This information was received from Dr. Josef Jablonowski, and Dr. Summers was instructed to take up his investigations in that region. Unfortunately it was impossible for him to arrive in the infested forest until after the feeding of the caterpillars was finished and most of the eggs for the new brood of moths had been laid. Parasites were not present to any marked extent at this time, which was not surprising, owing to the fact that the observations were made too late in the season. Some evidence was secured that the wilt disease was present in the area, but a fairly good increase of the species was noted except at points where the trees had been completely denuded and where the caterpillars had died from starvation or had moved to

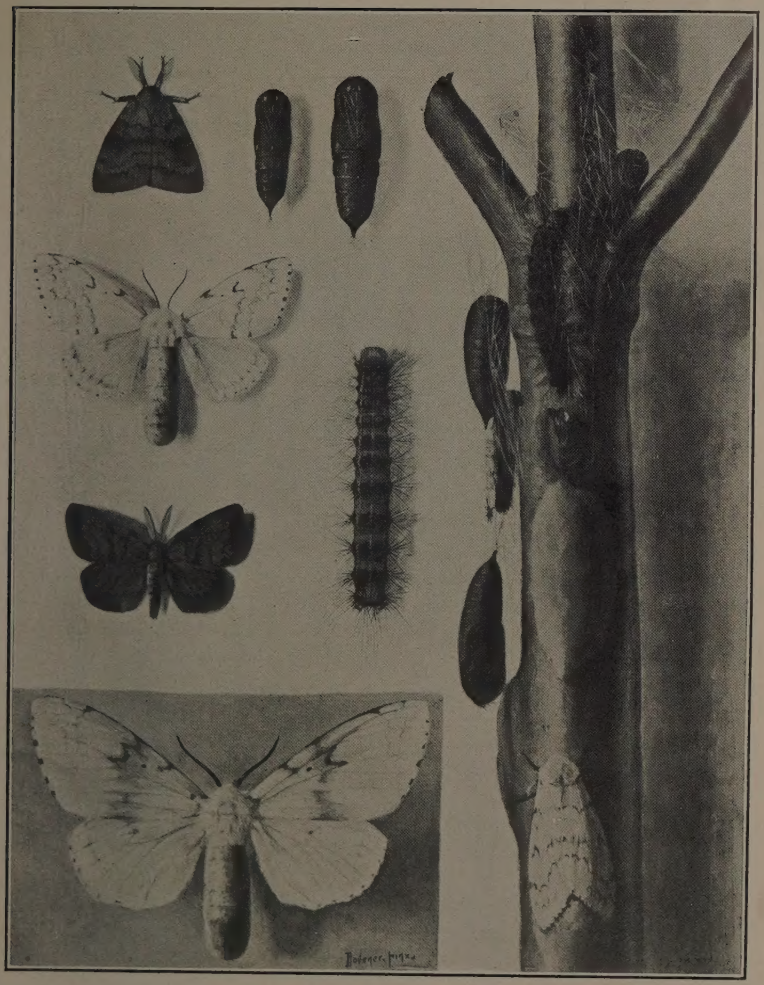
adjoining tree growth in search of food. Dr. Summers estimates that not less than 5,000 acres were almost completely defoliated in the forests in Hungary where he made his observations. The growth consisted entirely of hardwoods; the oak predominating, and a species of Carpinus, beech, and maple occurring in the order mentioned. A few elm trees were also present.

The results of the European investigations carried on during the past few years, aside from furnishing a good supply of parasitic species, has proved beyond question that as far as the forests are concerned the character of the growth is of prime importance from a gipsy-moth point of view. Coniferous forests predominate in Germany, and these are not injured by the gipsy moth. The deciduous forests in that country are not large, and the injury is periodical and severe. In Hungary large deciduous forests are present and the infestation is more or less common from year to year. Severe defoliation usually continues for about three years before a marked decrease of the moth is observed, and then a few years pass before another outbreak is noticed. This information, with certain data which have been collected in this country for the past few years relative to the increase or decrease of the gipsy moth under New England forest conditions, together with a careful study of the feeding habits of the gipsy-moth caterpillar in all its stages on the various species of tree growth, and the beneficial influence which is being felt to a greater extent each year as a result of the increase of the parasites and natural enemies of the moth and the severity of the wilt disease, all point the way to more effective methods of handling the gipsy-moth problem.

The different phases of the experimental work, as it is being carried on, will be touched upon briefly in order to indicate the changed conditions which are being brought about in the infested area in New England.

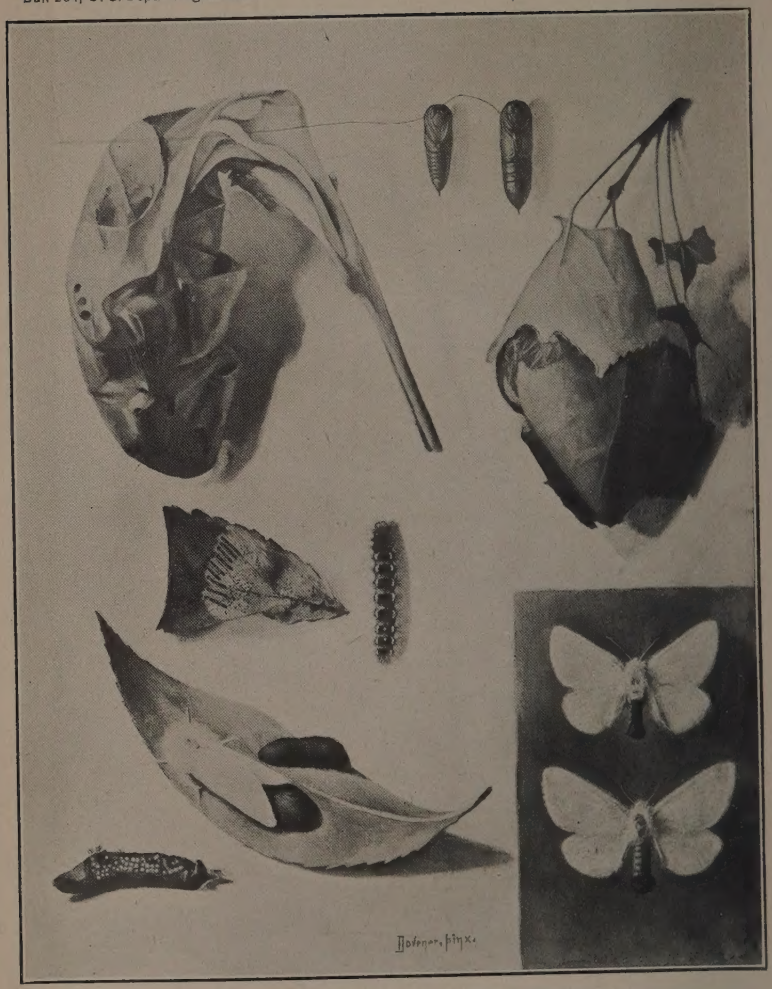
PARASITE WORK.

As has already been stated, the first attempts to introduce the parasites and natural enemies of the gipsy moth and brown-tail moth were begun in 1905. In all more than 30 enemies of these insects, which are present to a greater or less extent in their native homes, have been introduced into New England. More than half of the species have been received in sufficient numbers so that colonies could be liberated under field conditions, and they have had an opportunity to demonstrate their ability to withstand climatic conditions and to become established in this country. As should be expected, a large number of the species have failed to survive. A few have been recovered from year to year, showing that while they have the ability to maintain themselves, they have not yet been able to increase to a sufficient extent to become a useful factor in controlling their hosts. A few species have become established and are increasing satisfactorily. In fact, some of them are making sufficient headway so that they have already become a very appreciable



THE GIPSY MOTH (PORTHETRIA DISPAR).

Upper left, male moth with wings folded; just below this, female moth with wings spread; just below this, male moth with wings spread; lower left, female moth, enlarged; top center, male pupa at left, female pupa at right; center, larva; on branch, at top, newly formed pupa; on branch; just below this, larva ready to pupate; on branch, left side, pupæ; on branch, center, egg cluster, on branch, at bottom, female moth depositing egg cluster. All slightly reduced except figure at lower left. (From Howard and Fiske.)



THE BROWN-TAIL MOTH (EUPROCTIS CHRYSORRHOEA).

Upper left, hibernating web; just below this, small larvæ feeding at left, larger larva at right; just below this, female moth depositing eggs at left, egg mass at right; lower left, egg mass with eggs exposed; top center, male pupa at left, female pupa at right; upper right, cocoon incased in leaves; lower right, male moth above, female moth below. All slightly reduced. (From Howard and Fiske.)

factor in reducing the infestation of the gipsy moth even under our adverse food-plant conditions. The most valuable species will be mentioned briefly in order to give an idea of their habits.

FIG. 1.—*Anastatus bifasciatus:* Adult female. Greatly enlarged. (From Howard.)

Two species of minute hymenopterous parasites which attack the eggs of the gipsy moth have become established in New England. One, *Anastatus bifasciatus* Fonsc. (fig. 1), occurs in Europe and Japan, and although only one brood of this insect is reproduced each

FIG. 2.—*Schedius kuvanae:* Adult female. Greatly enlarged. (From Howard.)

season, it has succeeded in maintaining itself and increasing in practically every locality in which it has been liberated. The other species, *Schedius kuvanae* How. (fig. 2), was imported from Japan.

A brood of this species develops under favorable weather conditions in about four weeks. The first brood appears in August and the insect continues to breed until cold weather sets in. Owing to the fact that several broods develop in a single season, the insect increases very rapidly. It can be reared in the laboratory for the purpose of colonization, and this work is being done each year. Unfortunately the insect does not always survive the winter in good condition, so that its occurrence in the colonies where it is liberated is by no means as uniform as that of Anastatus.

Apanteles lacteicolor Vier. (fig. 3) is a small hymenopterous parasite which deposits its eggs in the small caterpillars of the brown-tail moth in August. The eggs of the parasite hatch in the body of the small caterpillar, but development is very slow during the fall. Caterpillars that are attacked in this way feed and enter the hibernating web with their more fortunate comrades. They pass the winter and emerge with the others early in the spring. As soon as they have become active and begin feeding the Apanteles larva also begins feeding and by the time the caterpillar is about one-fourth of an inch long this internal parasite has become large enough to destroy it. The Apanteles larva then makes its way from the body of the caterpillar, forms a cocoon (Pl. III, fig. 1), and early in June the adult parasite emerges. This is the time of year when small caterpillars of the gipsy moth are feeding, and the parasites attack these caterpillars and pass through one generation with the gipsy moth as a host.

FIG. 3.—*Apanteles lacteicolor:* Adult female and cocoon. Much enlarged. (Original.)

Another species which attacks both the gipsy and brown-tail moth caterpillars is a parasitic fly known as *Compsilura concinnata* Meig. (Pl. III, fig. 2). This insect is about the size of the house fly, although its habits are strictly those of a caterpillar parasite. Early in the spring the female fly deposits a small maggot in the body of the larva of the brown-tail moth which feeds inside the body of the caterpillar and becomes full-grown early in June. At this time the maggot burrows through the epidermis of the host and forms a puparium from which, in about a week, the adult fly emerges. This brood attacks the gipsy-moth caterpillars, the adult

flies emerging early in July. One or more broods may follow before cold weather in case native larvæ are at hand to serve as hosts.

A species of Apanteles (*A. melanoscelis* Ratz.), which was received in small numbers from Italy in the summer of 1912, was liberated near the laboratory at Melrose Highlands, Mass. It is double-brooded, both generations being passed on gipsy-moth caterpillars. This species has maintained itself since its introduction and promises to be a most valuable addition to the enemies of the gipsy moth. It has not been imported or recovered in sufficient numbers from the colony liberated in this country so that other colonies could be established, but is considered a very valuable species.

The Calosoma beetle (*C. sycophanta* L.) (Pl. IV), while not strictly a parasite, is at the present time doing more effective work against the gipsy moth than any single introduced species. This large green beetle hibernates in the ground during the winter and emerges about the first of June. It feeds on the caterpillars and pupæ of the gipsy moth and brown-tail moth, as well as on such native species as it may find. These beetles climb trees and are continuously searching for food. They live two or three years and after midsummer burrow into the ground where they remain during the winter. On the average, 100 eggs are deposited in the ground annually by each female. The beetle larvæ hatch in about a week. They are proficient tree climbers and feed constantly on the caterpillars and pupæ of the gipsy moth or other insects until they become full grown about the middle of July. This species has increased and spread in a most satisfactory manner, and has made great inroads on the gipsy moth in many localities. Both the beetles and the larvæ attack the caterpillars of the brown-tail moth, so that double benefit results.

Another parasite, one which attacks the brown-tail moth only, is a hymenopteron known as *Meteorus versicolor* Wesm. It has become well established, but is seldom found in great numbers. It is possible that this species may increase rapidly later on, but at the present time it does not appear to be as beneficial as those that have previously been mentioned. Several species of introduced tachinid flies are recovered occasionally, but in such small numbers as to indicate that they are not at the present time doing effective work.

An enormous amount of careful study and a large number of detailed experiments have been carried on in order to determine the life histories, habits, and utility of the different species which have been introduced. It has been necessary from time to time to develop new methods of handling these species in order to get the data desired, and practically all the equipment and breeding devices

used at the laboratory are of original design and have been constructed for the purpose of furthering the gipsy-moth investigations. Much valuable information of a biological nature has been secured which is not only of direct value to the parasite phase of the gipsy-moth work but has been found useful in connection with insect problems in various parts of the country.

RECENT COLONIZATIONS AND RECOVERY OF IMPORTED PARASITES.

During the past two or three years careful investigations have been carried on to determine the increase and spread of the different parasites. In the summer of 1914 this work was in charge of Mr. S. S. Crossman. As large a number as possible of the different species have been liberated in the remote parts of the infested area for the purpose of securing the establishment of these valuable species over the entire territory at the earliest possible date. In the fall of 1913 *Anastatus bifasciatus* was recovered from 41 towns and the parasitism in the collections secured averaged about 30 per cent. From one collection over 43 per cent of the eggs had been destroyed by this insect. As a result of the collection made during the winter, 1,561 colonies of this species, totaling 1,561,000 specimens, were liberated; 1,047 of the colonies were placed in 12 towns in Massachusetts and 514 in three towns in New Hampshire. This insect spreads very slowly, hence it is necessary to liberate many colonies. The plan which is being used is to place a sufficient number of colonies in a town so that no further colonization in that town will be necessary. The work on this insect required the collection in the fall of 1913 of about 7,500 gipsy-moth egg clusters and these were secured from over 100 selected localities.

In the fall of 1913, 33 towns were colonized with *Schedius kuvanae*. The number of colonies placed in a town varied from 1 to 10, depending on the gipsy-moth infestations. Most of the colonies were liberated in the southern part of the infested territory in Massachusetts, as it was believed that this section would be favorable for the survival of the species during the winter. In all 110 colonies were liberated, containing over 375,000 individuals. This species spreads more rapidly than Anastatus, so it is not necessary to place as many colonies in a given area. Over 14,000 gipsy-moth egg clusters were collected from about 100 selected localities within the area bounded by Exeter, N. H., and Berlin, Bolton, and Mashpee, Mass. This material was used at the laboratory to secure records of the percentage of parasitism in colonies that had been liberated in previous years.

The spring of 1913 was very favorable for *Apanteles lacteicolor*, and it was recovered from 69 towns. This was the result of collections of 92,000 brown-tail moth webs, a supply coming from every one of

FIG. 1.—COCOONS OF APANTELES LACTEICOLOR IN MOLTING WEB OF THE BROWN-TAIL MOTH. (ORIGINAL.)

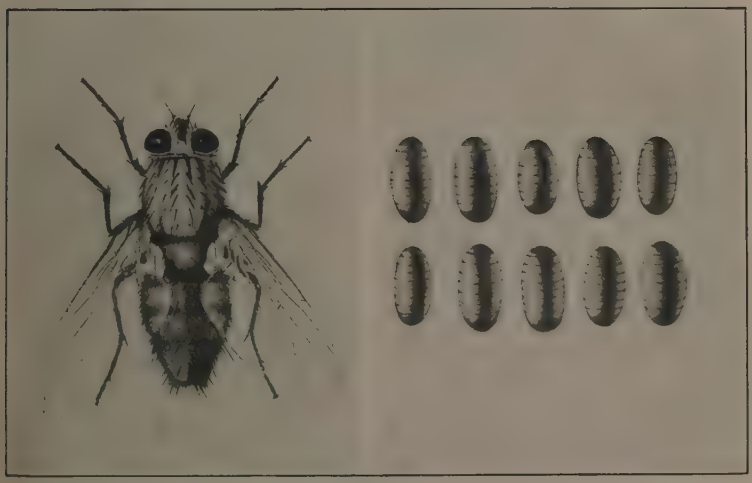


FIG. 2.—THE COMPSILURA FLY (COMPSILURA CONCINNATA): ADULT FLY, MUCH ENLARGED, AT LEFT; PUPARIA, ENLARGED, AT RIGHT. (ORIGINAL.)

THE CALOSOMA BEETLE (CALOSOMA SYCOPHANTA).

Upper left, eggs; lower left, adult beetle feeding on gipsy moth caterpillar; upper right, gipsy moth pupæ destroyed by Calosoma larvæ; center, Calosoma larva, ventral view; right center, Calosoma larva, dorsal view; lower right, Calosoma pupa in cavity in ground. (From Howard and Fiske.)

the New England States. Fifty-six colonies were liberated in 48 towns, a total of over 76,000 cocoons being placed in the field. During the winter of 1913–14 collections of brown-tail moth webs were made in 72 towns scattered over the infested area in New England. The recovery of the parasite indicates that it has become established as far north as Monson, Me.; west as far as North Adams, Mass.; and south as far as Waterford, Conn. About 2,500 cocoons were liberated in the spring of 1914 in three of the Connecticut Valley towns in Vermont. Our work on this species was supplemented by cooperative work which was carried on by Prof. W. C. O'Kane, State entomologist of New Hampshire. From collections made by his assistants he was able to colonize Apanteles in 11 towns, 1,000 specimens being put in most of these colonies. Similar work is carried on in cooperation with the gipsy-moth laboratory by Maj. E. E. Philbrook, State moth superintendent of Maine, but a definite statement of the number of colonies liberated can not be given at this time. An arrangement was made during the fall of 1913 to continue cooperative parasite work between the laboratory and the entomologist of the Dominion of Canada, Dr. C. Gordon Hewitt. In the spring of 1914 he detailed one of his assistants, Mr. L. S. McLaine, to take up work in Massachusetts, using the gipsy moth laboratory as headquarters. Mr. McLaine secured several assistants, and as a result of his efforts about 1,000 Apanteles cocoons were sent to the brown-tail moth infested area in New Brunswick for the purpose of colonizing the species. Similar efforts were made the previous year and colonies were liberated in New Brunswick and Nova Scotia, and in several of these places the species survived the winter of 1913. (Pl. V.) In general it should be said that the winter of 1913–14 resulted in a marked decrease in the abundance of Apanteles. An unusually high mortality of caterpillars in the brown-tail webs accounts for this decrease. The exact cause of the mortality of the brown-tail moth caterpillars can not be definitely stated, but it seems to be attributable to an unusually severe winter, the presence to a greater or less extent of internal parasites in the caterpillars, and the effects of the brown-tail fungus, a disease which also affects the larvæ of this species.

The parasitism of the gipsy moth by *Apanteles lacteicolor* was not nearly as high in 1914 as during the previous year, and was of course a direct result of the failure of the brown-tail moth caterpillars to bring through the first generation of the parasite.

During the summer of 1913 *Compsilura concinnata* was recovered from 54 new towns. Eleven of these were in Maine, 14 in New Hampshire, and 29 in Massachusetts. In the summer of 1914 this insect was found in 44 new towns—2 in Maine, 21 in New Hampshire, 20 in Massachusetts, and 1 in Rhode Island. It is possible that

Compsilura is present in more localities in Maine, but we have been unable to secure definite records to that effect. The following table is interesting, as it shows the general rate of dispersion of this parasite. The spread recorded is based on distance from Melrose Highlands, Mass., and is mostly due to natural spread, although a few small colonies have been liberated outside of the area where the species was known to occur in 1913.

TABLE I.—*Dispersion of Compsilura concinnata. Distance recovered from Melrose Highlands, Mass.*

	1913	1914
From Melrose Highlands:	*Miles.*	*Miles.*
North	75	100
Northeast	100	130
South	50	50
Southwest	40	55
West	50	65
Northwest	70	80

It is undoubtedly true that this species is now present over an area which would be represented by connecting the points indicated by the directions and distances given in the table for 1914. (Pl. VI.) Four thousand five hundred and sixty-five Compsilura were liberated in 10 new towns in 1913 and 10,000 were placed in 21 new towns in 1914, as follows: Eight in New Hampshire, 5 in Vermont, 2 in Massachusetts, 2 in Rhode Island, 3 in Connecticut, and 1 colony was forwarded to a substation of the Bureau of Entomology at Koehler, N. Mex., in order to test the value of this species as an enemy of the range caterpillar (*Hemileuca oliviae* Ckll.), an insect which is causing enormous damage to the grazing lands in that State. In addition to the number of specimens of this species colonized in 1914, about 5,000 were secured by Mr. McLaine and shipped to New Brunswick; about 3,000 were secured by Mr. R. S. Ferguson, assistant in the moth department of the State of Maine, who, with several assistants, were collecting for the purpose of establishing colonies in that State, and over 2,500 were collected and colonized by Prof. O'Kane's assistants in New Hampshire.

Three hundred and sixty-five sample collections of gipsy-moth larvæ which were secured during the summer of 1914 from scattered localities in Maine, New Hampshire, Massachusetts, and Rhode Island, consisted of over 99,000 caterpillars. This material required the use of over 500 rearing trays at the laboratory and the constant attention of several assistants to feed the larvæ in each tray and record the parasitism, mortality, and other data.

Based on 25 collections of gipsy-moth larvæ taken at widely scattered points in the gipsy-moth-infested area and aggregating 46,000

specimens, an average of 20 per cent of parasitism by Compsilura was found to exist. Several large single colonies showed a degree of parasitism ranging from 40 to 50 per cent. The results secured with this species during the summer of 1914, based on the number of parasites obtained from the collections, indicate that the distribution of this insect is more likely to be local than general, since in areas where it was abundant in the summer of 1913 it was recovered in very small numbers in 1914, in spite of the fact that a moderate infestation was present during the latter year.

Apanteles melanoscelis, a species already referred to, is showing considerable promise. As high as 19 per cent of the second stage gipsy moth larvæ collected at Melrose Highlands during the summer of 1914 were parasitized. This species was recovered from two new towns this year, namely, Stoneham and Saugus.

Considerable additional data have been secured from other imported parasites which have been colonized in this country and have survived in more or less numbers. The details are not given, however, inasmuch as it has not been demonstrated thus far that they are of particular value as parasites of either the gipsy moth or the brown-tail moth.

Pteromalus egregius Först. has been recovered in small numbers from many parts of the territory infested by the brown-tail moth. The larva of this insect works as an external parasite of the small brown-tail moth caterpillars in the webs. *Monodontomerus aereus* Walk., a parasite of gipsy and brown-tail moth pupæ, is known to occur throughout most of the area infested by these insects. It has been reared in small numbers from tachinid puparia and undoubtedly has other unrecorded hosts.

Calosoma sycophanta has been found during the summer of 1914 over a much wider area than that previously recorded (Pl. VII). Owing to the ease with which the beetles and their larvæ could be collected in the field it has been possible to liberate 37 colonies in New Hampshire, Massachusetts, Rhode Island, and Connecticut. These were placed outside the area where the species was previously known to occur. In addition, colonies of Calosoma have been liberated in Maine and New Hampshire by State officials. Colonies have been liberated in New Brunswick, Nova Scotia, and Quebec as a result of collections made by Mr. McLaine and his assistants, and 1,700 specimens were collected by Mr. H. E. Smith and forwarded to Koehler, N. Mex., to test their value as an enemy of the range caterpillar.[1]

[1] This work was carried on by arrangement with Mr. F. M. Webster, who is in charge of the Cereal and Forage Crop Insect Investigations of the Bureau of Entomology.

As a result of the Calosoma scouting work carried on during July and August, 1914, it has been found that this species exists in 18 towns in Maine, 93 in New Hampshire, 170 in Massachusetts, 3 in Rhode Island, and 2 in Connecticut. Data concerning this insect obtained during the present year indicate that the species is able to maintain itself in considerable numbers in areas where the gipsy-moth infestation is slight and that as a rule the species continues to be abundant after it once becomes established in a locality. Owing to the well-known habits of the beetles in migrating considerable distances, it was thought that territory with light infestation would be deserted in favor of areas where caterpillars occurred in abundance. This does not prove to be the case and it is another feature which increases the value of this beneficial insect.

The table below shows the colonization of the principal parasites during 1913 and 1914:

TABLE II.—*Colonization of natural enemies in 1913 and 1914.*

Species.	Number of colonies liberated.		Number of individuals liberated.		Towns where colonies were placed.	
	1913	1914	1913	1914	1913	1914
Anastatus bifasciatus[1]	1,500	1,561	1,500,000	1,561,000	[2] 42	15
Schedius kuvanae	110	502	352,000	2,093,254	33	111
Apanteles lacteicolor[1]	56	14	76,000	13,119	48	14
Compsilura concinnata[1]	10	28	4,565	23,638	10	26
Calosoma sycophanta[1]	45	49	6,175	8,104	42	38

[1] A part of the collections and colonization were made by cooperative arrangements with the State officials of Maine and New Hampshire, with the Dominion Entomologist of Canada, and with Mr. F. M. Webster of this bureau.

[2] In many of these towns only a few colonies were liberated.

The results of the work accomplished by introduced parasites of the gipsy moth during the past year have been excellent. It is true that the increase of *Apanteles lacteicolor* has been seriously retarded but the other species have given a good account of themselves. The fact that Compsilura and Calosoma are becoming established in the remote parts of the area infested with the gipsy moth and are able to maintain themselves under these conditions is very encouraging, as the work of these species will tend to reduce the infestation and be an important factor in preventing the spread along the outside border.

WILT-DISEASE INVESTIGATIONS.

In connection with the parasite work and having a distinct influence on the increase of the gipsy moth in the field, an elaborate series of experiments has been conducted by Mr. R. W. Glaser and several assistants for the purpose of securing information on the identity of the wilt disease (Pl. VIII) and the factors which are favorable to its increase in the field.

THE WILT DISEASE OF THE GIPSY MOTH. (ORIGINAL.)

Note the typical way in which these caterpillars hang when affected by this disease.

This work has been carried on at the Bussey Institution, Forest Hills, Mass., and a sublaboratory in charge of Mr. J. J. Culver has been maintained during the summer at Worcester, Mass., where special experiments have been conducted to determine the relation of favorable and unfavorable food plants to the development of the disease. A series of field experiments was also conducted in a selected area at Lunenburg, Mass., by Mr. A. W. Young and Mr. R. T. Webber, who made continuous observations in a limited area on the development of the disease under field conditions, with particular reference to the relation of temperature and humidity. Several other points were selected in Massachusetts where continuous temperature and humidity records were secured, as well as at the Lunenburg area, and a careful compilation of this data is expected to give information as to the weather conditions which are most favorable for the development of this disease.

For a number of years the wilt disease has been found in the field in nearly all places where heavy gipsy-moth infestation exists. During the last year or two it has occurred in light infestations and very few localities in the infested area are known where it is not found to a greater or less extent.

The results of the season's work indicate that the disease has been slightly less prevalent during the past summer than the previous year and this was particularly true during June and the first part of July. Cool weather prevailed at this time. Late in July the large caterpillars in many places were seriously affected, so that the increase of the gipsy moth was not as great as was anticipated early in the season.

The technical studies on the wilt disease are very difficult to conduct because it is almost impossible to secure healthy material for experimental purposes. The organism is believed to be a filterable virus and is so minute that it easily passes through the finest bacteriological filters that have yet been devised. It belongs to the same class of organism as yellow fever and a number of other contagious diseases, although all of these were, at one time, supposed to be caused by bacteria. The period when gipsy-moth caterpillars of moderate size are available for experiments covers about six weeks, and this adds to the difficulty of carrying on investigations on account of the limited time when material can be secured. During the past year it has been determined that the wilt disease, or a similar organism, affects eight of our common native caterpillars in addition to the gipsy moth. It is also known to attack the silkworm (*Sericaria mori* L.) and nun moth (*Porthetria monacha* L.), a fairly common European species which is very destructive to pine. Good results have been secured this year, but a large amount of work is necessary

in order to establish the essential facts concerning the identity of the organism and the conditions most favorable for its increase and development.

FOOD-PLANT INVESTIGATIONS.

As has already been pointed out, the species of tree growth have an important relation to the ability of the gipsy moth to increase and cause serious damage in the field. Nearly 20 years ago food-plant experiments were conducted in this country to determine the species upon which the gipsy moth would subsist, and a long list of food plants was published by Forbush and Fernald in their excellent book on the gipsy moth. Most of these experiments, however, were carried on by using large caterpillars and feeding them in jars or cages in the laboratory. At that time it did not seem important to determine whether there was variation in the feeding habits of the caterpillars in different stages. As early as 1908 it was observed and proven by an extensive field experiment that the first-stage caterpillars of the gipsy moth could not develop on white pine in the absence of other food. This naturally led to the question of unfavorability of other species to gipsy moth attack. In 1912 a careful series of food-plant experiments was begun. Mr. F. H. Mosher took charge of this work and has been furnished with a number of assistants during the feeding season. The feeding was carried on in individual trays, which were specially constructed for the purpose. One hundred first-stage caterpillars were placed upon a branch of foliage in each tray. In this way the feeding habits could be observed, the foliage renewed daily, and it was possible to determine which food plants were least subject to attack under laboratory conditions. Similar experiments were carried on with caterpillars in the succeeding stages. This work was continued in the summers of 1913 and 1914, so that up to the present time about 250 species of trees and shrubs have been tested.

As a result of these experiments some of the more common species are rated as follows:

I.—Species favored by the gipsy-moth larvæ in all stages:

Alder, speckled.[1]	Oak, black.
Ash, mountain.[1]	Oak, chestnut.
Aspen.[1]	Oak, post.[1]
Balm of Gilead.[1]	Oak, red.
Basswood.	Oak, scarlet.
Beech.	Oak, swamp white.
Birch, gray.[1]	Oak, white.
Birch, paper.	Poplar, big toothed.[1]
Birch, red.[1]	Shadbush.[1]
Boxelder.[1]	Willow.[1]
Larch.	Witch hazel.[1]

[1] Species of low commercial value.

II.—Species favored by the gipsy-moth larvæ after the first stage:

Chestnut.	Spruce, black.[1]
Hemlock.	Spruce, Norway.
Pine, hard.[1]	Spruce, red.
Pine, red.	Spruce, white.[1]
Pine, white.	

III.—Species not favored by the gipsy-moth larvæ but capable of supporting it:

Beech, blue.[1]	Maple, red.[1]
Birch, black.	Maple, silver.[1]
Birch, yellow.	Maple, sugar.
Cherry, black.	Pignut.
Elm.	Sassafras.[1]
Gum, black.[1]	Shagbark.
Hornbeam, hop.[1]	

IV.—Species unfavored by the gipsy-moth larvæ in all stages:

Arborvitæ.	Fir, balsam.[1]
Ash, black.[1]	Hackberry.[1]
Ash, white.	Locust, black.
Butternut.	Locust, honey.
Cedar, red.[1]	Sycamore.[1]
Cedar, white.	Tulip.

[1] Species of low commercial value.

During 1914 many food plants were tested which do not ordinarily occur in New England except when planted for ornamental purposes. They grow to a greater or less extent in other sections of the United States, and it was desired to make these tests in order to determine whether these plants would be seriously damaged by the gipsy moth in case it should spread from New England. The information is also useful as a guide to the method of treatment which should be applied in case a small colony should become established in some region outside the present infested area. During the first two summers that these experiments were carried on a sublaboratory was maintained at Worcester, Mass., where check experiments were conducted. The food-plant work is now nearly completed and the results will be brought together shortly for publication. In connection with these experiments it should be said that a large number of observations have been made in the field each summer relative to the favorability of different species of trees and undergrowth to gipsy-moth attack. This information serves as a check on the laboratory experiments which are carried on under artificial conditions. The observations in the field have in the main been made in definite areas, which were selected for an entirely different purpose and will be considered under the next experimental project.

EXPERIMENTS IN DETERMINING THE INCREASE OF THE GIPSY MOTH IN THE FIELD.

In view of the importance of parasites, disease, and unfavored food plants in reducing the increase of the gipsy moth, it seemed desirable to secure definite data on the normal increase of this insect in the field and the increase where these deterrent elements were present in varying degrees. The most feasible way to determine the increase is to compare the number of egg clusters in a given locality from year to year. In order to do this arrangements were made in the fall of 1911 to study field conditions in a systematic manner. About 250 areas which have been designated as "observation points" were selected throughout the infested area. This gave an opportunity for ascertaining the effect of latitude, seasonal variation, and altitude on the increase of the species. In selecting these points an attempt was made to secure as many pure stands of forest growth as possible; also, to obtain areas of mixed growth where the proportion of favored food plants varied. Areas were also secured where different species of parasites had been liberated and where the wilt disease had occurred abundantly or in a small amount during the previous year. The degree of infestation was also considered in making a selection and a number of points were obtained where the trees had previously been defoliated to check against some where no defoliation had resulted and the infestation was very light. After an area was selected a tree was marked for a center and a circle 100 feet in diameter was laid out. Each tree within the circle was numbered consecutively and a note made of its species, size, and condition. In the fall, as soon as the foliage had dropped, a careful count was made of the egg clusters on each tree. These results have been secured and tabulated as well as exact information relative to the number of egg clusters found on the ground and undergrowth. Records have also been kept on the condition of the trees from year to year, and the number of trees which died in each area has been carefully noted. The condition of the territory surrounding these points, as regards infestation, has also been noted. This work has been supervised by Mr. C. W. Minott, but it has not been carried on for a sufficient number of years to give all the exact information desired.

The following table gives the gross number of egg clusters found in the points each year, and will be of interest as indicating in a general way the severity of the infestation from 1910 to 1914.

It will be noted that 170 points are given in the table. The balance of the 250 which were originally selected have been discontinued, owing to destruction by fire, promiscuous cutting by the owners, or for other reasons. The area in the points aggregates 30.18 acres, and the surrounding territory which has been watched brings the total under observation up to 863.1 acres. For convenience, the

infested territory has been divided into five sections, and the towns in which the points were located are indicated on the accompanying map.

TABLE III.—*Gipsy moth egg clusters recorded in observation points, 1910–1914.*

Locations.	Number of points.	Egg clusters.				
		1910	1911	1912	1913	1914
Eastern New Hampshire and Maine	32	2,074	31,751	29,637	26,147	18,234
Western New Hampshire	33	14,885	23,032	28,618	9,603	13,228
Northern Massachusetts	34	29,399	47,419	30,345	17,603	31,316
Western Massachusetts	30	10,742	26,409	28,301	9,763	17,159
Southern Massachusetts	41	11,486	39,319	42,451	8,222	31,065
Area, 30.18 acres	170	68,586	167,930	159,352	71,338	111,002

The count of the egg clusters recorded under 1910 was made in the fall of 1911 and covered all clusters which were found to have hatched and therefore belong to the 1910 brood of moths. This count was more or less inaccurate, as many of the egg clusters were removed from the trees after a year's exposure to the elements. The count indicates, however, that there was a large increase in infestation between 1910 and 1911, and that in 1912 the gross infestation was slightly reduced. A heavy reduction occurred in 1913, while in 1914 a considerable increase was noted but not nearly as great as was the case from 1910 to 1911.

The conclusion which will inevitably be drawn from these figures will not apply to other localities in the infested area. There are many locations where a marked increase was noted in 1913 or where a marked decrease was noted in 1914, but taking the territory as a whole it gives a general idea of the trend of increase or decrease for the period covered.

Knowing the conditions, one can not fail to be impressed with the results that have already become apparent from the introduction of parasites and the work of the wilt disease. Although the season of 1914 was not as favorable to the natural enemies as was the case in 1910, the proportional increase in the number of egg clusters was considerably smaller. Unfavored food plants have, of course, been instrumental in holding down the increase in some of the points, but the amount of infestation in points where unfavored food predominates has remained rather constant, so that it has not been as great a factor in the reduction noted as the other elements just mentioned.

Much careful work has been required to secure this data. For about six months in each year upward of 20 men have been engaged in this work. During the summer a part of the men made observations on the feeding habits of the gipsy moth caterpillars on different food plants in their sections. Observations on the presence of

natural enemies were also made and from time to time collections of egg clusters or caterpillars near the points were obtained and sent to the laboratory in order that the percentage of parasitism might be determined. This work should be continued in order to determine whether after the natural enemies become firmly established the outbreaks of this insect will be periodical over a large territory or whether, as is the case at the present time, the smaller colonies will increase so that stripped areas will be found scattered over the entire region.

DISPERSION WORK.

For the past three or four years considerable attention has been paid to the means by which the gipsy moth spreads. As the female moth does not fly it is apparent that the dispersion of the species must be very slow unless it is carried by other means. Egg clusters may be transported on lumber, forest products, Christmas trees, or other material which is likely to be shipped long distances from the infested area. This matter has been given careful consideration and means have been taken to prevent the spread of the moth in this way. Information concerning methods used are given under the quarantine part of this report.

In the spring of 1910 a number of experiments were conducted which showed that first-stage gipsy-moth caterpillars may be carried by the wind, and the information secured at that time has been published.[1]

Since this work was carried on more elaborate experiments have been conducted by Mr. C. W. Collins and assistants, to obtain long-distance records on the spread in this manner. A study has also been made of the likelihood of the insect being spread by caterpillars drifting in streams, or by wood or other material which is infested with egg clusters floating in rivers and becoming lodged in territory which was not infested. At present wind spread seems to be the chief natural means by which the insect becomes established in new territory. The trend of the spread is toward the north and northeast on account of the fact that the warm prevailing winds before the first of June, when the caterpillars are in the first stage, usually blow in those directions. This has resulted in a large increase in the area infested in Maine, and the territory in that State will probably continue to extend as long as large areas are seriously infested in New Hampshire and Massachusetts. The western spread of the insect has probably been greatly retarded by reason of the fact that low temperature, causing the caterpillars to be inactive, has prevailed when the winds came from the east or northeast. Heretofore serious infestation did not occur in southeastern Massachusetts or Rhode Island; hence winds from the southeast were not an important factor in

[1] Burgess, A. F. The dispersion of the gipsy moth. U. S. Dept. Agr., Bur. Ent., Bul. 119, 62 p., 16 pl., 6 fig., 1 map, Feb. 11, 1913.

causing spread into Connecticut or the area in Massachusetts south of Worcester. Recently, however, the infestation has increased to a great extent in southeastern Massachusetts and Rhode Island, and unless vigorous means are taken to abolish these sources of supply, rapid infestation of eastern Connecticut and territory in Massachusetts lying immediately north of that State will result. In fact, during the past season a large increase has been found in the western tier of towns in Rhode Island and the eastern tier in Connecticut. In eastern Connecticut the white oak, which is one of the most favored food plants of the gipsy moth, is exceedingly common in the woodlands, and the difficulty of controlling the moth under these conditions is very great.

A series of experiments has been conducted to determine how far male moths will be attracted by the females. The purpose is to determine the probability of scattered females being fertilized if they occur at a long distance from a gipsy-moth colony.

SECONDARY INSECT INVESTIGATIONS.

In the fall of 1912 large numbers of oak trees in the areas that had been defoliated by the gipsy moth were found in a dying condition. Examination showed that many of the trees had been attacked by a bark borer, which proved to be *Agrilus bilineatus* Web. The matter was taken up with Dr. A. D. Hopkins, in charge of Forest Insect Investigations of the Bureau of Entomology, and arrangements were made for cooperative study of this insect. Dr. Hopkins was to direct the work, and the salary and expenses of an assistant, Mr. H. A. Preston, who was to give his entire time to the work, were to be paid by this branch. Investigations have been carried on and the life history of the insect worked out. It appears from the information secured that continuous work on this project is not necessary, and the cooperative arrangement was discontinued July 1, 1914. The data relative to the life history and habits, as well as control measures, is in the hands of Dr. Hopkins and will doubtless be published at an early date.

For the information of woodland owners who wish to preserve their oak trees it can be stated that all trees which are in a dying condition in September should be marked so that they can be cut during the winter. The wood should be removed from the lot and if it can be used for fuel the hibernating larvæ will be destroyed. Inasmuch as the oak is very favored as a food plant by the caterpillars of the gipsy moth and as the Agrilus beetles prefer to attack weakened trees, it would seem rather difficult to preserve oak growth unless considerable expense was involved in spraying or treating gipsy-moth egg clusters in order to keep the trees in a vigorous condition. This is impracticable in most woodlands in the infested area. Park or ornamental trees can be handled in this way and the cost is not prohibitive.

RESULTS OF EXPERIMENTAL WORK.

Many of the experimental projects which have been undertaken are nearing completion and detailed reports will be published later.

The information on food plants will now form a definite basis for practical work, and as has been brought out by the observations in Europe on both parasites and food-plant conditions, it will be necessary to bring about in our forests a great reduction of the favored food plants of the gipsy moth before natural enemies can be expected to keep this insect within reasonable bounds.

The parasites and wilt disease, as has already been shown, are doing effective work, but the results would be greatly amplified by eliminating favored food plants.

The study of the increase of the moth in the field furnishes valuable data on all phases of the forest control problem, while the work on dispersion is of special value in connection with the field control work which is being carried on.

Secondary insects are important inasmuch as they may prevent the recovery of many trees which have been defoliated and which would, under normal conditions, gradually recover.

SILVICULTURAL WORK.

During the time the gipsy moth has been known to exist in this country it has done an immense amount of damage to tree growth of the infested region. The injury has caused the death of many of the trees attacked or the retardation of their growth and development, and has produced conditions favorable to the increase of secondary enemies. The tree growth affected may be divided into three classes, (1) fruit trees, (2) shade or ornamental trees, and (3) forest trees. All have suffered severely, but owing to their greater value and relatively smaller numbers it has been possible to prevent a large amount of the injury by applying hand methods of suppression to fruit and shade trees. Gipsy-moth damage to forest trees, however, can not be controlled in the same way owing to the great expense involved, hence the problem of preventing damage in woodlands is a serious one. In some European countries this has been solved to a considerable extent by growing species which are not so susceptible to gipsy-moth attack. The investigations on the food plants and feeding habits of the gipsy moth indicate that the work of eliminating the most susceptible and encouraging the growth of those that are not favored as food by this insect is likely to give good results. As this work involves, to a considerable extent, the practice of silviculture, the Bureau of Entomology requested and received the cooperative assistance of the Forest Service, and these two branches of the Department of Agriculture are now working together on this problem. Mr. George E. Clement, who was formerly an assistant in the Forest

Service, has been appointed to take charge of the investigations along this line. The table given under the "food-plant experiments" indicates in a general way the degree of susceptibility to moth attack of some of our more common forest trees. Certain species, however, are of little commercial value, and it is desired to discourage their growth, as well as those that are particularly susceptible to gipsy-moth attack. In the case of valuable species that are susceptible to attack and for the growth of which a large portion of the infested region is favorable, the only step which can be taken is to determine whether or not they can be sufficiently protected from serious damage by associating with the less susceptible species in small proportions. Of course, the presence of these species may jeopardize the safety of the associated species which would otherwise be immune. However, before abandoning these species careful experiments will be made to determine whether there are associations with which they can join with safety.

The chief fact that reduces the liability of certain species of trees, particularly conifers, to gipsy-moth attack is that the *very young* caterpillars do not feed upon them. Therefore, if there are present no trees or undergrowth upon which the young caterpillars will feed and thereby develop to a size which enables them to attack conifers or similarly susceptible species, they will not be attacked. Thus it appears that certain species can be grown pure or in exclusive association and be free from gipsy-moth attack. Any system of forest management should endeavor to produce in a given area only trees of commercial value, and the foregoing lists (pp. 14–15) indicate the most suitable species for selection.

In converting a given stand of timber into one which shall be immune from gipsy-moth attack, the different classes of trees should be considered for removal in the following order:

(1) Trees of naturally low commercial value and susceptible to gipsy-moth attack.

(2) Trees of low commercial value on account of growing in unfavorable situations and susceptible to gipsy-moth attack.

(3) Trees of commercial value, favorably situated, and subject to gipsy-moth attack.

(4) Trees of naturally low commercial value, but not liable to gipsy-moth attack if properly associated.

(5) Trees of low commercial value on account of growing in unfavorable situations and not liable to gipsy-moth attack.

(6) Trees of commercial value favorably situated and not liable to gipsy-moth attack.

Silvicultural conditions in the woods of the infested region are very poor. Through repeated fires and heavy and inconsiderate cutting, the growth of weed trees has been greatly favored and the growth of

some species has been favored in situations quite unsuited to their requirements. This is particularly true in the case of the oaks and gray birch. These species constitute a very large proportion of the deciduous growth of the region and are very susceptible to gipsy-moth attack. On a great deal of the area now covered by these species the white pine would grow to much better advantage, would yield a much more valuable product, and if pure, or nearly so, would prove immune to gipsy-moth attack. The white pine reproduces itself readily under favorable conditions, and is already fairly abundant in numerous localities. For these reasons the white pine recommends itself very strongly as a substitute for the existing moth-susceptible species, and this species has been considered to a very large extent by this department in its experiments to create a safe stand of timber. The deciduous species which are of value and immune to gipsy-moth attack require most favorable situations for their profitable development, and such situations are very few and of small area. An exception in the case of chestnut may be made in this connection. This is a valuable tree and one well suited to grow over a considerable area. Its growth is not recommended on account of its susceptibility to the widespread and fatal chestnut blight. But, like the red oak, it may be found possible to grow it satisfactorily in small numbers with other species.

EXPERIMENTAL WORK.

The experimental work has been conducted by means of small areas known as "sample plats." These vary in size from one-half an acre to 6 acres and occur both scattered and grouped in different parts of the infested region. They are necessarily located on the lands of private owners who are willing to submit their lands to this use.

An effort has been made to distribute this work as widely as possible over the infested region. (Pl. IX.) In this way the greatest variety of conditions is encountered and the results are available to the greatest number of woodland owners. Each sample plat varies from another in one or more of the following points: Composition of stand, age of stand, degree of infestation, and method of treatment. Each sample plot generally consists of two parts. One of these is the portion upon which actual experimental work is done and the other serves as a control or check plat. Upon the latter nothing whatever is done, as its purpose is to provide a means of comparing results under natural and artificial conditions. The corners and boundaries of all plats have been plainly marked, and the areas surveyed and mapped. All trees 1 inch and over in diameter have been calipered on each plat and control, and the measurements recorded. Forest descriptions of each plat have been written.

Where small white pines have occurred in any quantity they have been counted and the numbers have been recorded by foot-height classes. The best available indication of the degree of gipsy-moth infestation seems to be the number of egg clusters, and for this reason the egg clusters have been counted on each plat. Egg clusters will be counted periodically in the future in order to determine the effect of treatment upon the infestations.

After the foregoing steps have been taken, the growth on each of the managed areas has been thinned. Different silvicultural systems have been used, but in general the object has been to remove the greatest number of susceptible trees consistent with the silvicultural requirements of the trees to be left. In some cases the bulk of the stands consisted of susceptible species, and in these the thinning made was preliminary to a later clear cutting.

After cutting, the number of trees of different diameters and species have been counted and recorded, the amounts of products have been measured and recorded, brush has been piled and burned, careful notes of the changed conditions have been made, and an effort has been made to compute the cost of the work and the value of the products on each plat. In some cases numbers of small naturally produced white pine have been supplemented with planted 2-year-old seedlings from the nursery. In cases where plantings were made the cost of the seedlings and the planting was borne by the owner of the woodland. In addition to the sample plats already mentioned, one 10-acre tract has been selected in each of the following towns in New Hampshire: Peterboro, Franklin, Warner, and New Durham. The growth on all these plats is largely inferior hardwoods which are particularly liable to gipsy-moth attack. The infestation in each case is not heavy. As there is more or less white pine growing among the hardwoods the plan is to cut the latter clean and to replace these trees by planting enough white pine to produce a stand which will be free from gipsy-moth damage. The results of these experiments will not be available for several years, and during this period careful notes on conditions will be made.

MIDDLESEX COUNTY FOREST SURVEY.

In order to get some definite information concerning the distribution of the various kinds of timber stands in the region, a rough forest map of the county of Middlesex in Massachusetts has been made. This work has shown that the forest growth is very uneven and complex, and that there is a wide variation in the composition of stands within relatively small areas. The existing growth of trees on any area indicates very infrequently the growth for which the conditions on the area are best suited. From data secured by this survey and observations made throughout the infested region, the crying silvi-

cultural need of the woods is obviously a great reduction of their diversity and the replacement of a large portion of the species by those which have a greater commercial value, and for which the conditions for growth are much better adapted. The steps needed to accomplish this are in many instances precisely those which appear to be necessary in controlling gipsy-moth attack by silvicultural practice.

PROPOSED FOREST EXPERIMENT.

In order to determine the practicability of carrying on an experiment over a large area preliminary surveys have been made of the forest growth in the town of Winchendon, Mass. This work has been attempted in cooperation with the State forester of Massachusetts, Mr. F. W. Rane. The original growth in this town was undoubtedly coniferous, but there has been considerable cutting and as a result hardwood growth of various species has become established. Oak does not predominate, however, in this region and it is hoped that sufficient cooperation can be secured from the woodland owners in the town to handle the forest area so as to bring it into a growth which will not be susceptible to gipsy-moth attack. The preliminary survey has been completed and the data are now being compiled with a view to determining whether a plan of this sort can be worked out on an extensive area.

SCOUTING WORK.

The scouting work consists in examining the territory along the outside border of infestation, and in treating the gipsy-moth colonies adjacent to the border for the purpose of preventing spread of the insects to other parts of the United States. This work is in charge of Mr. L. H. Worthley, who is assisted by Mr. H. L. McIntyre. The territory is divided into six sections with the following men in charge of a section: Mr. D. G. Murphy, Worcester, Mass., H. A. Ames, Athol, Mass., H. N. Bean, Keene, N. H., F. W. Graves, jr., Bradford, N. H., F. W. Foster, Plymouth, N. H., and C. E. Totman, Canaan, N. H. Parties consisting of five trained scouts in charge of a foreman are detailed to make the examinations and treat the infestations, each general foreman having from 5 to 10 crews of scouts under his supervision. In order to check up the thoroughness with which the work is done in the lightly infested territory, a party, usually consisting of two experienced men who are known as special scouts, examines the work after the regular inspection has been made in order to see whether egg clusters of the moth have been missed and that the work was thoroughly done by the scouts. Each scout is required to place a characteristic mark on every tree examined by him so that the responsibility for leaving egg clusters can be readily determined. By following up this plan the force is maintained at a high degree of

efficiency, the careless and negligent men being dropped from the rolls. When large colonies are found crews of woodchoppers are employed temporarily to cut out the worthless trees and clean up the undergrowth in order to render the area in condition for effective operations.

The accompanying map (Pl. X) shows the territory which was known to be infested by the gipsy moth in the fall of 1913. In organizing the work a large party of scouts was sent to Maine for the purpose of determining whether the infestation had spread beyond this line. The results of the examination show that a large number of towns are infested outside the border previously established. The work was continued until late in December, when it was necessary to transfer the men on account of deep snow and extremely cold weather, the temperature for a number of days being as low as 20° to 25° below zero. In all, 155 towns were scouted in Maine, and of these 81 were found infested. The increase in the number of towns over that of previous years is largely explained by the fact that during the winter of 1912–13 the scouting work was not completed on account of snow and also because of the undoubted dissemination of the moth by means of the spread of the small caterpillars by the wind. The manner of this kind of spread has already been explained in this report. Suffice it to say, the general trend of dispersion of this insect has been toward the north and northeast on account of the fact that the prevailing warm winds during the time the caterpillars are hatching blow from the south and southwesterly directions. The work was continued from January until April in New Hampshire, Massachusetts, Rhode Island, and Connecticut.

On February 3, 1914, a report was received that several gipsy-moth egg clusters had been found on an estate at Bratenahl, Ohio, a suburb of Cleveland. The matter was at once investigated and two experienced scouts were detailed to make an examination of the estate and the surroundings. At the time the work was done there was considerable snow on the ground, making inspection work difficult. Seven new egg clusters were found and treated and later in the season the colony was burlapped and the trees sprayed. The work in Ohio was done in close cooperation with the Ohio Agricultural Commission, and work in the colony since the original scouting was done has been carried on by the assistants of Mr. N. E. Shaw, State nursery and orchard inspector.

On May 7, 1914, a report was received from Mr. George G. Atwood, chief of the division of horticulture of the State of New York, that a gipsy-moth colony had been found at North Castle, Westchester County, N. Y. Inspectors from this office were detailed to treat egg clusters, and several experienced scouts were transferred to assist in stamping out this colony. The principal infestation occurred on a large estate, and the caterpillars began hatching soon after the first

egg clusters were found. A considerable area was scouted around the infestation, and egg clusters or caterpillars were found over an area of about three-fourths of a square mile. Many of the trees were growing on rough and rocky soil, so that it was very difficult to do thorough work. About 15,000 egg clusters were treated during the month of May.

In addition to the scouting work already mentioned, a special examination was made of the entire town of Geneva, N. Y., but no gipsy-moth egg clusters were found. In 1912 a small colony was found in this city. It has been very thoroughly treated by the assistants of the commissioner of agriculture, and it is now believed that the insect has been exterminated. The scouting party detailed for the Geneva work spent one week in examining trees in Seneca Park, Rochester, N. Y., but no traces of the moth could be found.

Special scouting work was carried on in the towns of Lenox, Stockbridge, and Great Barrington, Mass., during the winter. Infestations have previously been found in these towns, but the examination resulted in finding but one egg cluster in Great Barrington, one in Stockbridge, and two in Lenox, indicating that good results have been secured from the treatment which had been applied during the previous season. A careful inspection was also made in the town of Wallingford, Conn., which was found infested some years ago, but no egg clusters were discovered.

The following table shows the number of towns which have been scouted for the gipsy moth and the number of new towns which were found infested during the winter of 1913–14.

TABLE IV.—*Scouting operations for the gipsy moth during the winter of 1913–14.*

State.	Towns scouted.	Newly infested.
Maine	155	81
New Hampshire	73	6
Massachusetts	36	7
Rhode Island	19	17
Connecticut	13	10
New York	3	1
Ohio	1	1

In nine towns in New Hampshire and two in Massachusetts, infested in 1912–13, no infestations could be found the following winter, and recommendations were made that these towns be excluded from the quarantined area. This was approved by the Federal Horticultural Board, and the border towns of the area quarantined for the gipsy moth include only those that have been found infested during the past winter.

The plan of the work has been to examine the territory in Maine chiefly for the purpose of securing data as to where the quarantine line should extend. It is impossible to prevent the spread of the small caterpillars by the wind, and it has therefore been deemed advisable to confine the clearing-up work along the border to the territory in New Hampshire, Massachusetts, Rhode Island, and Connec-

ticut. Accordingly early in the spring arrangements were made to place tanglefoot bands on trees in all the colonies about three towns wide along the border and from the time this work began the greater part of the scouting force was transferred to the work of applying and patrolling these bands.

In the colony in Westchester County, N. Y., 6,000 tanglefoot and 4,000 burlap bands were applied by the inspectors of the State department of agriculture. The State purchased a high-power spraying machine and very thoroughly sprayed the infested area and surroundings. The colony in Ohio was similarly treated by the State officials, and in both cases excellent results have been secured. This office has kept in constant touch with the work in these States and has also had a representative directing the work in the Berkshire Hills infestations in Great Barrington, Stockbridge, and Lenox.

Inasmuch as many of the new infestations were found on apple trees during the winter, a record has been kept of all such trees inspected and of the number of miles of roads scouted by the men. This information is given in the following table:

TABLE V.—*Results of scouting operations for the gipsy moth.*

State.	Towns scouted.	Colonies found.	Egg clusters found.	Apple trees inspected.	Miles of road traveled.	Tanglefoot bands applied.
Maine	155	.....	.....	764,081	4,768	.....
New Hampshire	73	1,656	25,427	1,354,908	4,334	68,336
Massachusetts	36	794	11,987	484,731	2,553	58,315
Rhode Island	19	[1] 309	[1] 207	232,190	987	5,324
Connecticut	13	[1] 157	[1] 124	332,036	884	4,767
Total	296	2,916	37,745	3,167,946	13,526	136,742

[1] In a number of these colonies pupa cases only were found.

The following conditions found in 1913 and in 1914 are of interest. In New Hampshire no egg clusters were found in 198 of the colonies that had been treated during the previous years, and in 641 of the 1,656 colonies found in the winter of 1913 no larvæ were found in the spring of 1914. In Massachusetts no egg clusters were found in 68 of the colonies that were treated during the winter of 1912–13, and in 124 of the 794 colonies located in the fall of 1913 no larvæ were found in the spring of 1914. In Rhode Island 276 of the 309 colonies found and treated in the fall of 1913 failed to produce larvæ in the spring of 1914. In Connecticut 136 of the 157 colonies treated in 1913 failed to produce larvæ the following spring.

During the summer of 1914 woodland scouting was carried on in Thompson, Conn., and Rutland, Mass. The former town is heavily wooded and is reported to contain about 30,000 acres of forest, a considerable part of which is oak growth. As a result of the examination of the woodland in this town 73 gipsy-moth colonies were discovered. All of them were small infestations, indicating that the species is established and is well scattered through the woodland.

GENERAL RESULTS SHOWN BY SCOUTING WORK.

The scouting work for the season has shown very encouraging results. In addition to the large number of towns along the outside border where the infestation has been greatly reduced or where it has been cleaned out during the past year, an excellent showing has been made in a number of badly infested towns in Massachusetts and New Hampshire which are just inside the border. In a large number of these towns which were found severely infested in the winter of 1912–13, a large decrease in the number of egg clusters has been found this year. In the town of Bradford, N. H., where over 3,000 egg clusters were treated during the former year, only 200 were found this season. In Hillsboro the records show a reduction of from 8,000 to 500, although the number of small colonies, many containing a single egg cluster, has increased. In Henniker and Warner, N. H., a large decrease has also been noted and the same is generally true in the border towns where work is being carried on.

The work on the tanglefoot bands during the entire season gave very gratifying results, and a very large number of the colonies where caterpillars were present early in the season showed no caterpillars or pupæ at the close of the work on tanglefoot bands on August 1. Only a few caterpillars were found in the western part of the area in New Hampshire, Rhode Island, and Connecticut.

No caterpillars were found in Lenox, Stockbridge, or Great Barrington, Mass. About 400 yards from the old infested area in the latter town 43 egg clusters were found in a rock heap during the caterpillar season which, of course, was under the snow when scouting work was done. Some very thorough work was done at this infestation, and only one pupa was found this season. Of course there is danger of some spread from it, and during the coming season some very thorough scouting will be done in this vicinity.

No caterpillars were found at Wallingford, Conn., this season.

In the badly infested woodland colony in Orange, Mass., where some 1,000 egg clusters were located, there were but 1,182 larvæ found during the summer.

The spraying work during the summer gave very satisfactory results, treatment being applied in border towns from Hubbardston, Mass., as far north as Andover, N. H. Many of the localities where spraying was applied were difficult to reach on account of being inaccessible from roads or water supply, but owing to the careful plans made by the foremen the work was not greatly handicapped on this account. In a number of cases the owners of the areas which were infested offered every cooperation possible in facilitating treatment. A few cases have been found, however, where spraying could not be attempted on account of the unwillingness of the owners to have their pasture trees treated because the grass was needed for grazing stock. In instances of this sort the infestations were cared for by creosoting egg clusters and destroying the caterpillars under tanglefoot bands.

BROWN-TAIL MOTH SCOUTING.

The spread of the brown-tail moth is not easily controlled by artificial means unless the insect can be reduced to minimum numbers. Owing to the large territory over which the insect has spread, it is not possible to carry on extensive scouting or control work by the use of hand-suppressive measures. During the year a considerable area, however, has been examined in Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and New York, and areas have been found infested where the insect was not known previously to exist. The work of the commissioner of agriculture of Vermont and his assistants has been very effective in reducing the infestation in that State. The principal new infestations were found in Connecticut, and a greater part of these were located by the assistants of the State entomologist. Several webs have also been found on Fishers Island and Long Island, N. Y., so that, in all, four towns on these islands are known to be infested. The New York infestations were discovered by the inspectors employed by the State department of agriculture, and several scouts from this office were sent late in the spring to check up the work and cover a part of the area concerned.

QUARANTINE WORK.

The quarantine work is supervised by Mr. D. M. Rogers, who is assisted by Mr. Harry W. Vinton, and the operations are confined to the territory in New England and New York which is infested by the gipsy moth and the brown-tail moth. As a result of the provision of the Federal plant quarantine act, which was passed by Congress August 20, 1912, a domestic quarantine [1] has been declared by the Federal Horticultural Board, covering the territory infested by each of these insects. While the legal authority for declaring quarantine is vested in the board, the cost of administering the work is defrayed by the appropriation for the Bureau of Entomology for "Preventing the spread of moths." The object of this work is to prevent egg clusters or larvæ of the gipsy moth, or winter webs of the brown-tail moth, from being carried out of the infested areas on shipments of trees or forest products. The regulations for enforcing this quarantine provide that all material of this character before being accepted for shipment to points outside the infested district must be inspected and must be accompanied with an official certificate of the Federal Horticultural Board stating that an examination has been made and that the material is free from infestation. Shipment of Christmas trees and similar material to points outside the quarantined area is prohibited. In order to facilitate the work, the infested territory has been divided into 22 sections and a competent inspector has been placed in charge of

[1] For details, see Notice of Quarantine No. 17, of the Federal Horticultural Board, effective Aug. 1, 1914.

each. (Pl. XI.) It is the duty of each inspector carefully to examine all lumber or forest products, cordwood, telephone poles, railroad ties, tan bark, etc., which may be shipped from any points in his district to points outside the infested area after the proper application has been made and to issue certificates of inspection if no infestation is found. In accordance with the provisions of the quarantine regulations, transportation companies are required to reject shipments which are not accompanied with proper certificates. During the season when nursery stock is being moved, examinations are made of all woody plants which are consigned to points outside the quarantined area. A number of special inspectors are employed for this purpose in addition to the men engaged on the regular lumber-inspection work. In order that this work may be of the most thorough character so as to safeguard purchasers in other parts of the United States, a tree-by-tree inspection is made of all trees and plants growing in the nurseries before they are dug for shipment. Another inspection of the plants is made at the time they are being packed for shipment. During the fiscal year 1914, 17,076 shipments have been examined and 4,476 specimens of the gipsy moth and 1,435 specimens of the brown-tail moth in their various stages have been found and the insects destroyed. This has resulted in preventing these pests from spreading to many localities not now infested. The destinations of these shipments ranged as far south as Jacksonville, Fla., as far west as Prineville, Oreg., and as far north as Montreal, Quebec.

The destination of shipments on which infestations were found and destroyed are given below:

State.	Number of shipments.	State.	Number of shipments.	State.	Number of shipments.
Colorado	1	Maine	12	Pennsylvania	10
Connecticut	25	Michigan	4	South Carolina	1
District of Columbia	1	Missouri	5	Vermont	35
Florida	3	New Hampshire	7	Virginia	2
Georgia	1	New Jersey	11	Canada	6
Illinois	14	New York	34	England	1
Iowa	1	North Carolina	1		214
Maryland	2	Ohio	12		
Massachusetts	24	Oregon	1		

BROWN-TAIL MOTH QUARANTINE.

The enforcement of the brown-tail moth quarantine is conducted in connection with the inspections carried on to determine whether shipments are infested with the gipsy moth. It is not necessary, however, to inspect lumber for this purpose. Deciduous nursery stock is examined and all webs of the moth destroyed before shipments are permitted. In order to prevent as far as possible the carriage of the adult female moths on trains, inspectors have been placed at several main railroad junctions along the border of infestations to examine the trains during the time the moths are flying. These insects are strongly attracted to bright light and the results which have been

secured from these inspections have been very satisfactory. The inspection work in 1914 began on July 6 and was continued until July 31.

The stations where trains were examined and the number of adults found are given below:

Station.	Brown-tail moths found.	Station.	Brown-tail moths found.
Bellows Falls, Vt	16	North Stratford, N. H	0
Greenfield, Mass	9	Springfield, Mass	1
Gorham, N. H	6	St. Johnsbury, Vt	457
Hartford, Conn	0	Wells River, Vt	247
New London, Conn	7	White River Junction, Vt	1,484

In addition to the foregoing, 296 adults were found and destroyed at arc lights in White River Junction, Vt.

RESULTS OF QUARANTINE WORK.

The results of the quarantine work have been very satisfactory. Only one infested shipment of plant products has been known to pass out of the territory and it was promptly returned.

Several carloads of stone and quarry products have recently been found infested with gipsy-moth egg masses and a quarantine was declared by the Secretary of Agriculture on October 23, 1914. Such products must now be inspected and certified the same as plant products.

Considering the number of infested shipments that have been found and the wide range of country to which they would have been sent if the egg clusters had not been found and treated, it is safe to assert that this work has resulted in enormous saving of money value to the agricultural and forest interests of the United States.

COOPERATIVE WORK.

Since the Federal work was commenced, active cooperation has been secured from the States in which operations were being carried on. While the organization of the State force and that of the Government force are entirely distinct the work is planned in such a way as to avoid duplication and to secure the best results. The general plan is for the Bureau of Entomology to concentrate its efforts in stamping out colonies in the territory along the western border of infestation from Lake Winnipesaukee to Long Island Sound, and to carry on as much work as may be necessary in eliminating the isolated colonies that have been found in New York, Ohio, western Massachusetts, and Connecticut. The State officials concentrate their efforts in the territory inside the border towns. Owing to the hearty spirit of cooperation that has existed between the Bureau of Entomology and the officials in New York, Ohio, and Connecticut, where isolated colonies are present, it has not been necessary for this office to expend much money for control work, as the States concerned have made every effort to stamp out these colonies. A system of following up and

checking over the work done by these States has been adopted, so that very satisfactory work has resulted. In the distribution of natural enemies arrangements have been made to cooperate with the State officials, and this has resulted in the establishment of more colonies of parasites than would otherwise have been possible. An arrangement has been made with the Massachusetts State Board of Agriculture so that speakers will be furnished to discuss the gipsy-moth problem at farmers' institutes.

In the spring of 1914 a colored poster was prepared showing the life histories of the gipsy moth and the brown-tail moth and several of the introduced natural enemies. These posters have been distributed to all the post offices in the infested district, to granges, libraries, and educational institutions. Reproductions from this poster have been made in the form of post cards and distributed to schools and parties interested in the work.

During October, 1914, an exhibit covering the gipsy-moth work of the bureau was made at the Boston Pure Food and Domestic Science Exposition, as a part of the Government exhibit. Living parasites were on exhibition as well as mounted specimens and other information.

Efforts are continually being made to advise property owners concerning the methods which should be taken by them to prevent serious damage to their trees, and good results are being accomplished along these lines.

CONCLUSION.

The gipsy-moth work of the Bureau of Entomology is well organized and each section is accomplishing good results.

The scouting work and the quarantine work are doing efficient service and preventing the spread of the gipsy moth, but on account of the enormous area which is infested it is impossible to cover much of the woodland. This has resulted in a gradual spread of the insect. It has been possible to restrict this spread very materially toward the westward.

The work of natural enemies, including the parasites, predacious enemies, and disease, have helped materially in decreasing the amount of infestation, and it seems probable that these influences will become more potent factors in the future.

The importance of bringing forest lands into a growth which is unfavorable to the development of the gipsy moth can not be too strongly urged, as the work of natural enemies is likely to fluctuate from year to year on account of adverse conditions or the decimation of the beneficial species by other parasitic forms. Every movement toward bringing about more unfavorable forest growth is therefore a step in solving the gipsy-moth problem.

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